

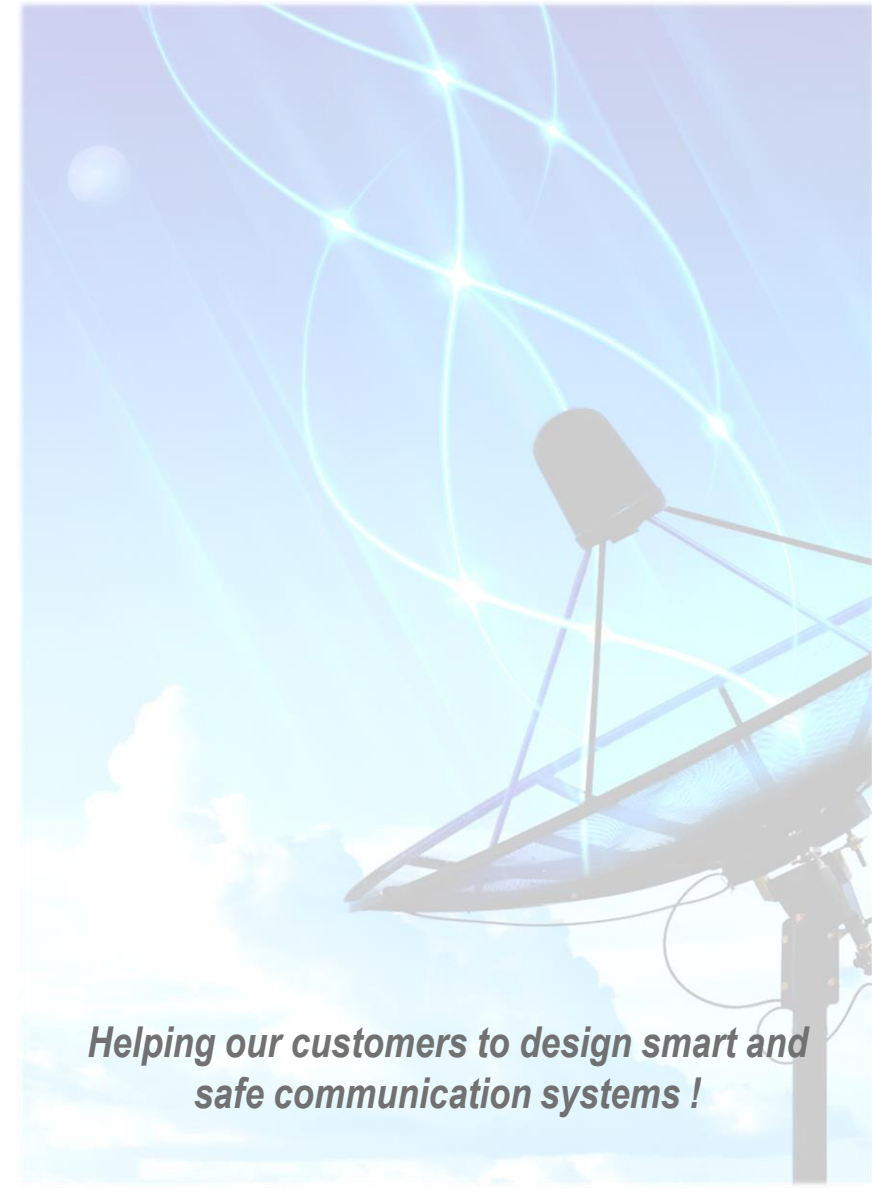
# Wideband Behavioral Modeling of Non-Linear RF blocks with Frequency Transposition and Memory Effects

**ZACHARIA OUARDIRHI**  
**APRIL 1<sup>ST</sup> , 2019**



# Agenda

- **About us**
- **Context of system design**
- **Behavioral modelling**
- **Identification methodologies**
- **Application examples**
- **Conclusion**



*Helping our customers to design smart and  
safe communication systems !*

# About Us

## Design Flow



COMPONENT

**IVCAD**



CIRCUIT

**IQSTAR**

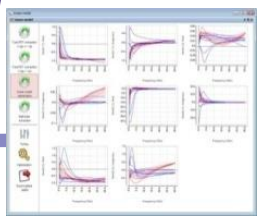


SYSTEMS

**VISION**



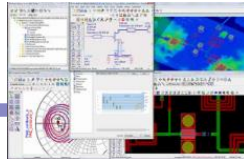
Pulsed IV and  
RF  
measurements



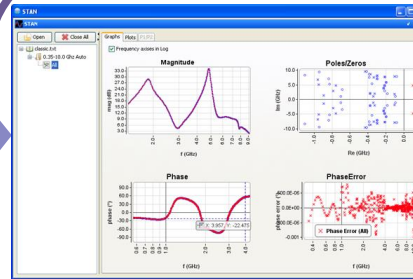
Compact  
FET model  
extraction



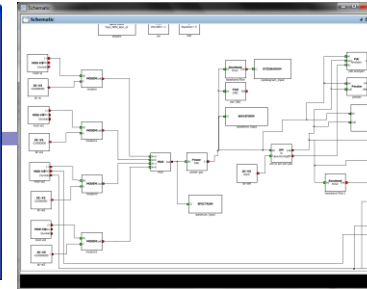
VNA based  
load pull



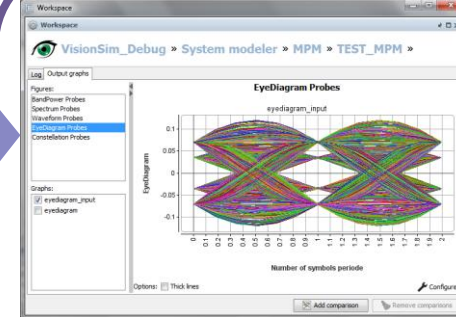
FET  
Compact  
model  
Validation &  
Refinement



IC Design &  
Stability analysis



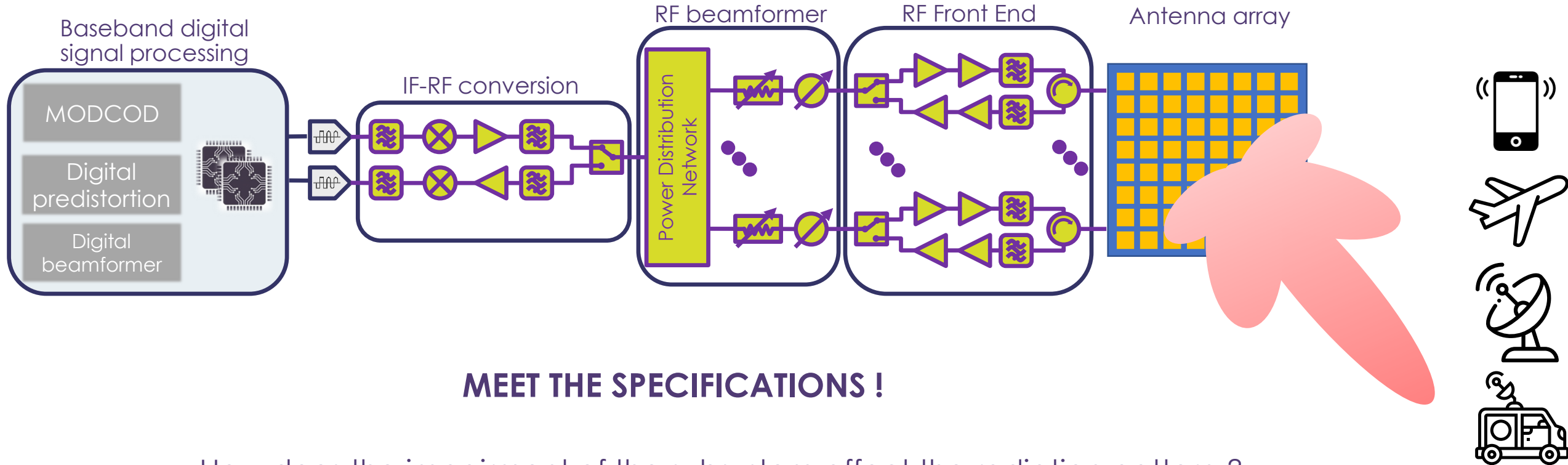
Circuit modeling



Simulation at system  
level

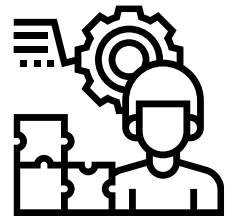
# Current challenges for system designer

## Complex mixed-domain analysis



- How does the impairment of the subsystem affect the radiation pattern ?
- Is my digital predistortion module powerful ?
- Is my beamforming algorithm efficient ?

=> Need of accurate behavioral models for RF subsystems compatible with system simulator



# Behavioral modelling of power amplifier

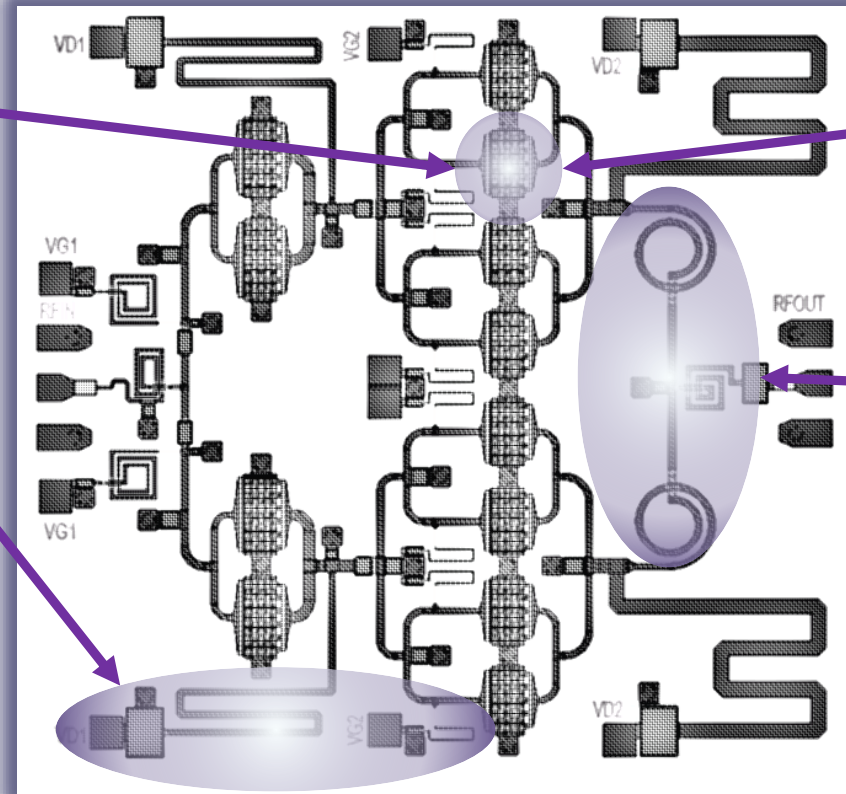
## Non-linearity and memory effects

Thermal effects  
Trapping effects

Transistors  
(transit time)

Biasing Circuits  
AGC Loops

Matching networks  
(group Delay)  
Band Filtering



Long time constant memory ( $\mu\text{s}$  to s, mins)

Short time constant memory (ns)

Long Term:  
Linked to the envelop  
modulation (baseband)  
Low Frequency memory

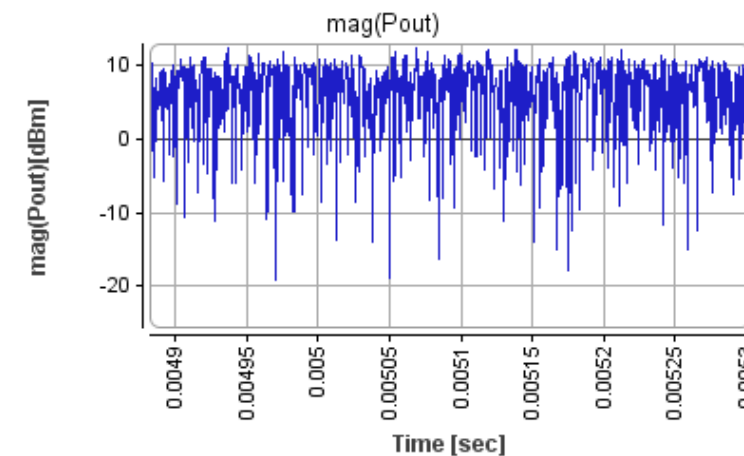
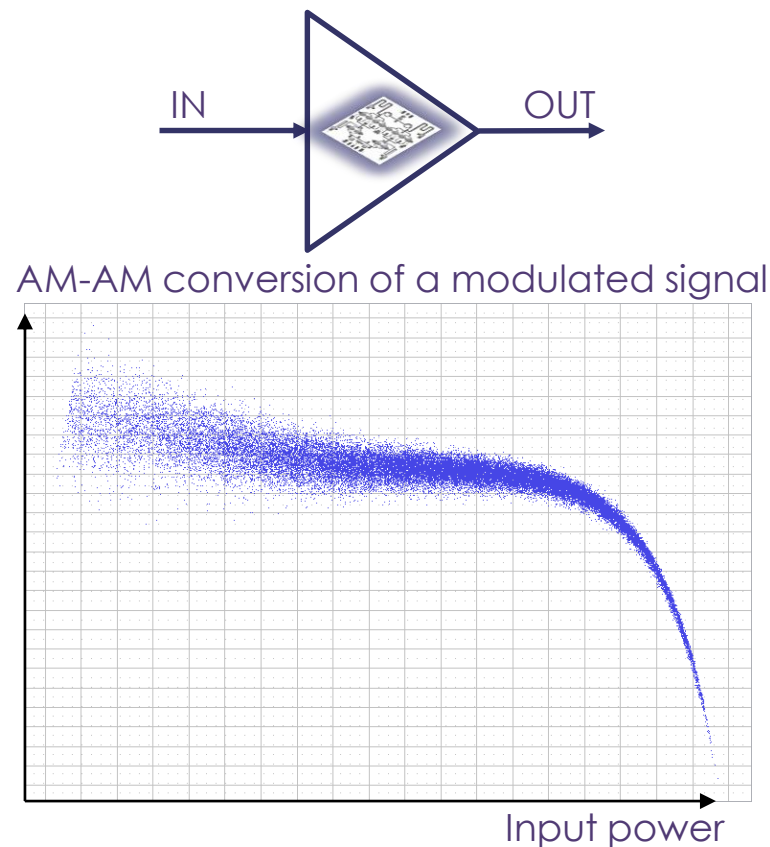
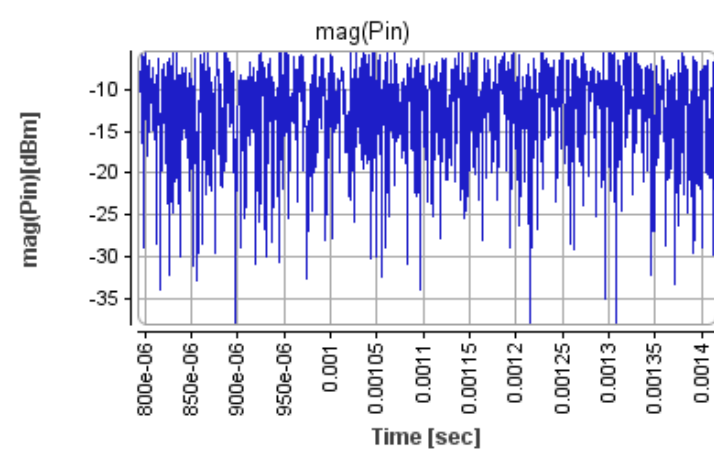
Mutual coupling

Short Term:  
Linked to the In-band  
response (carrier)  
High Frequency memory



# Behavioral modelling of power amplifier

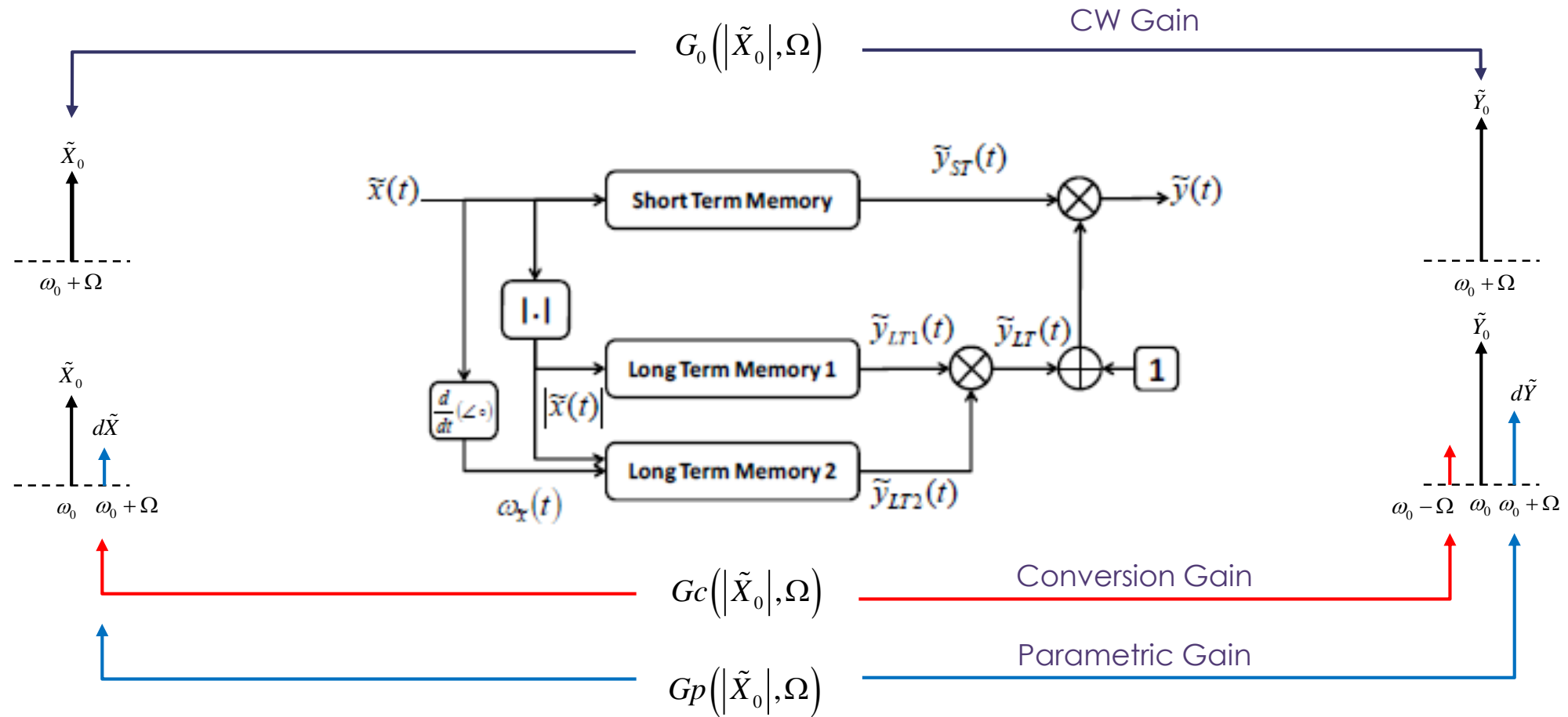
## Non-linearity and memory effects



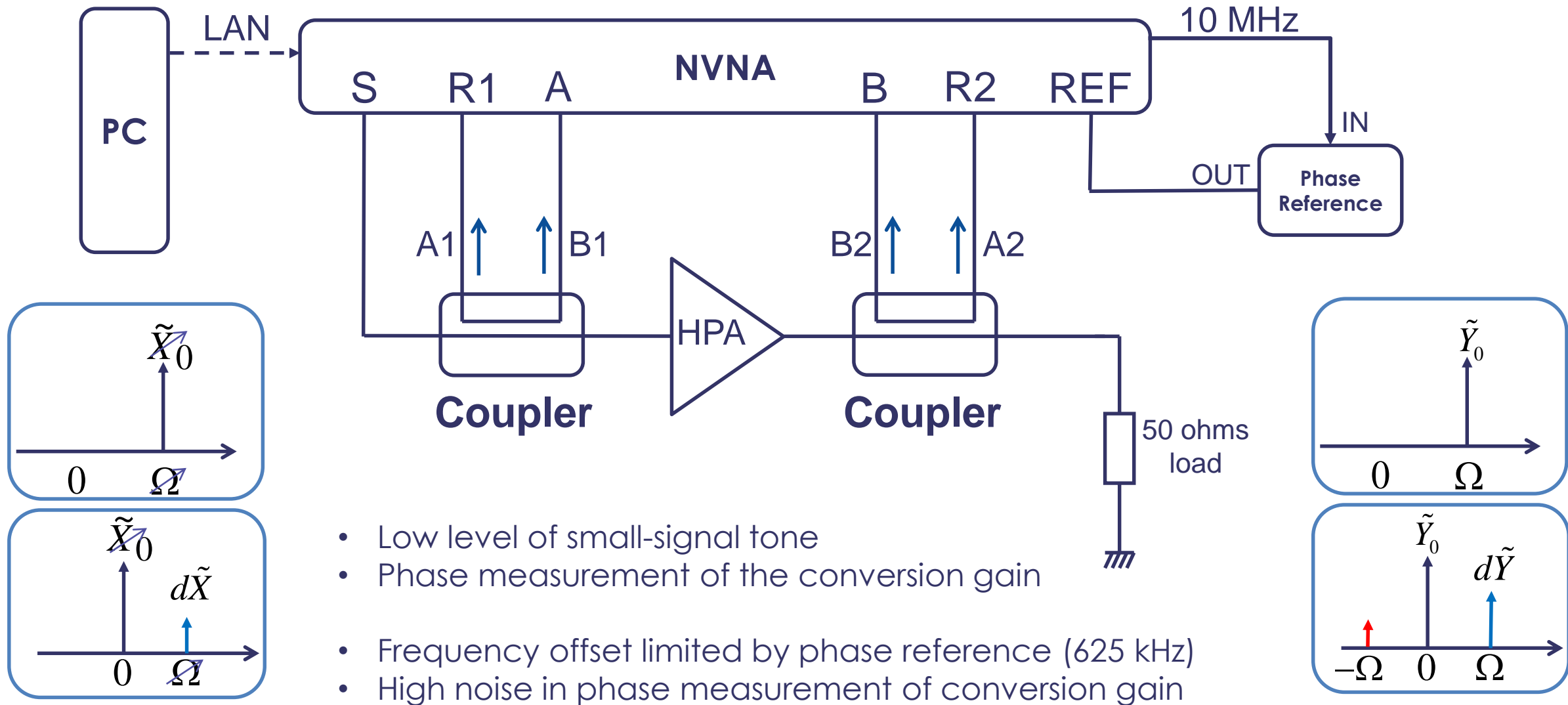
- Memoryless models are no longer accurate enough to represent PAs
- Output signal depends of input at the same time and previous samples in the certain duration of memory

# Behavioral modelling of power amplifier

## Two Path Memory Non-Linear Integral Model (TPM)

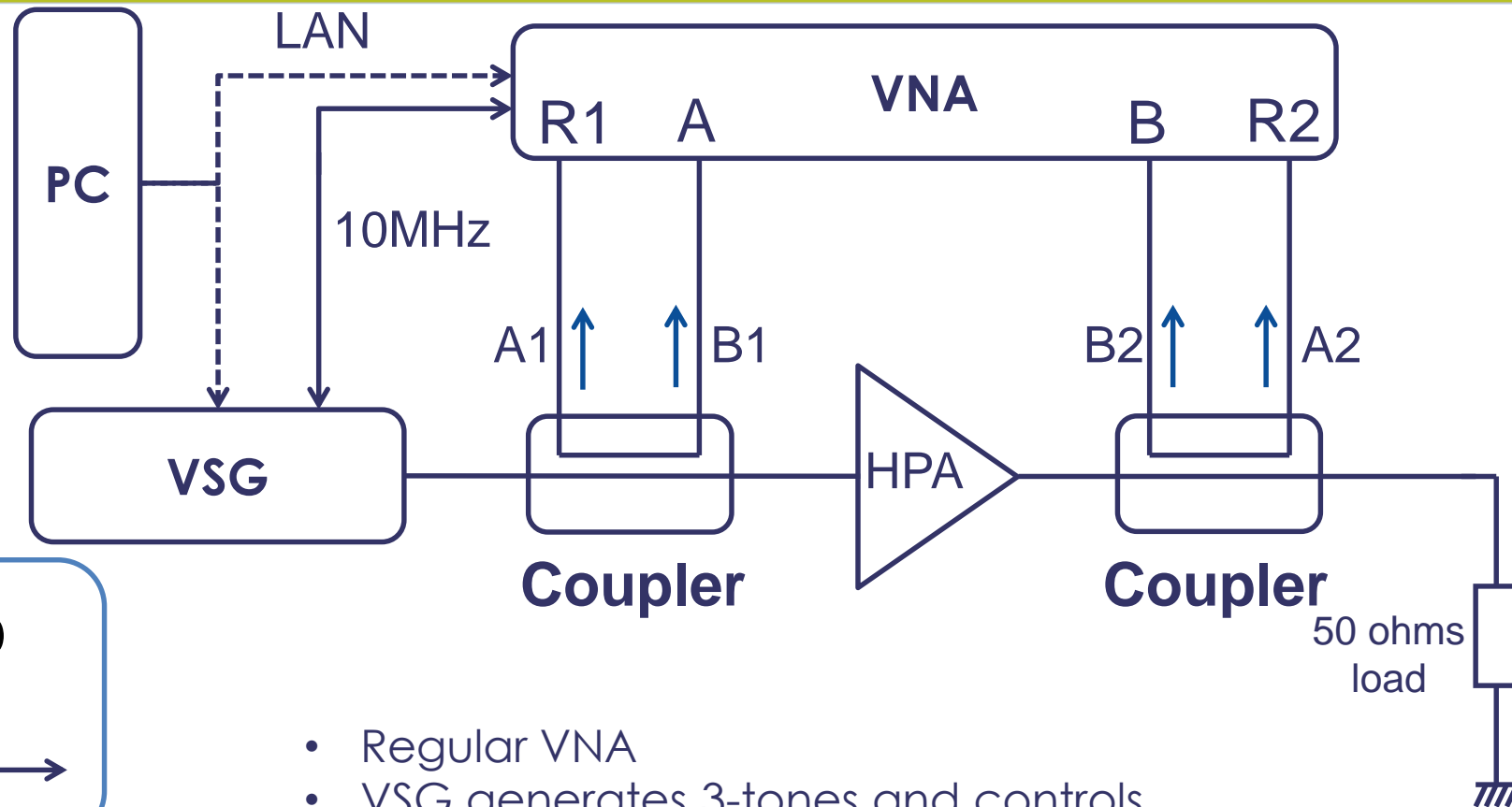


# Measurement setup for model kernel extraction

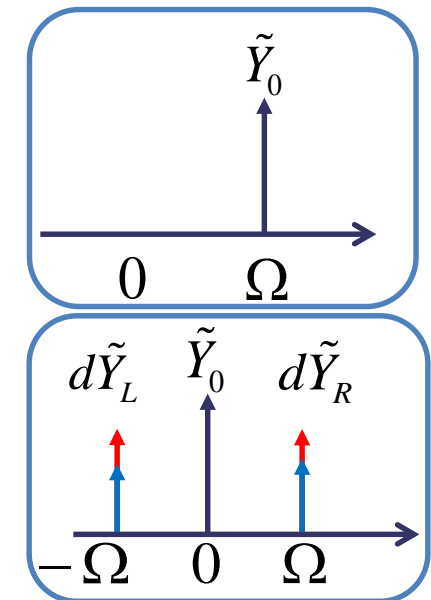
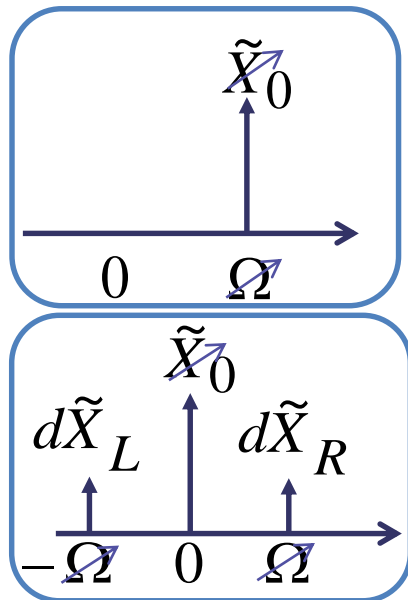




# New methodology extraction

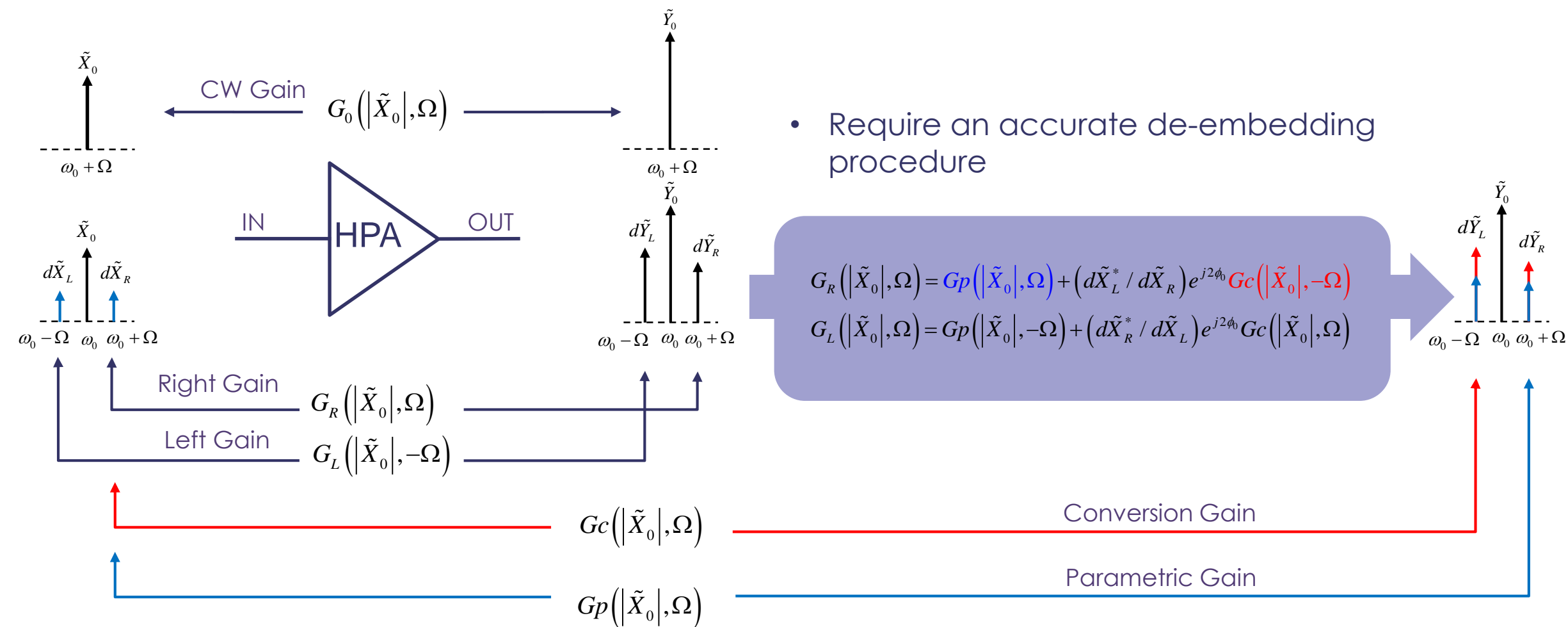


- Regular VNA
- VSG generates 3-tones and controls phase relationships between three input tones



# New methodology extraction

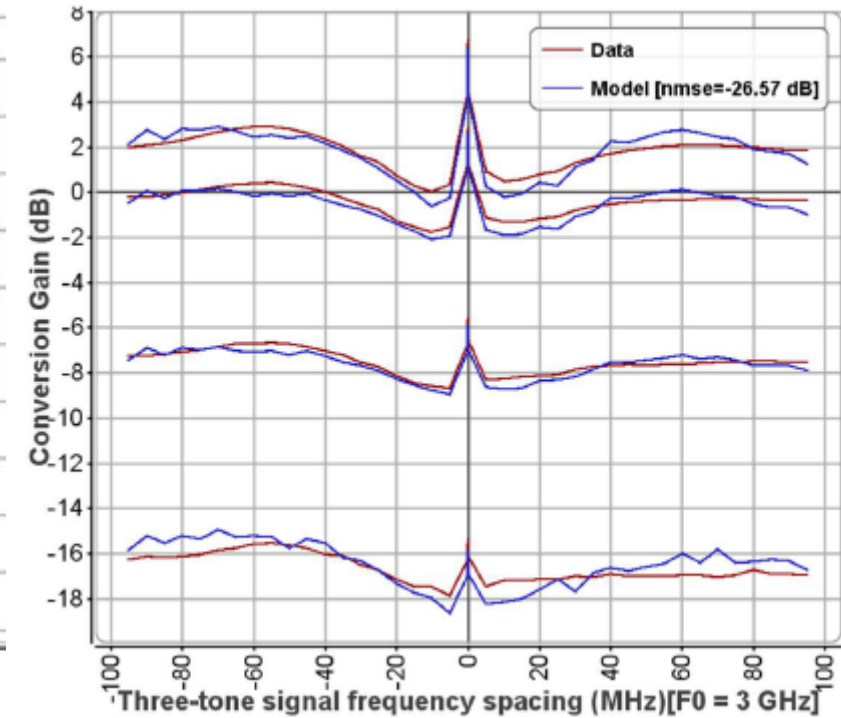
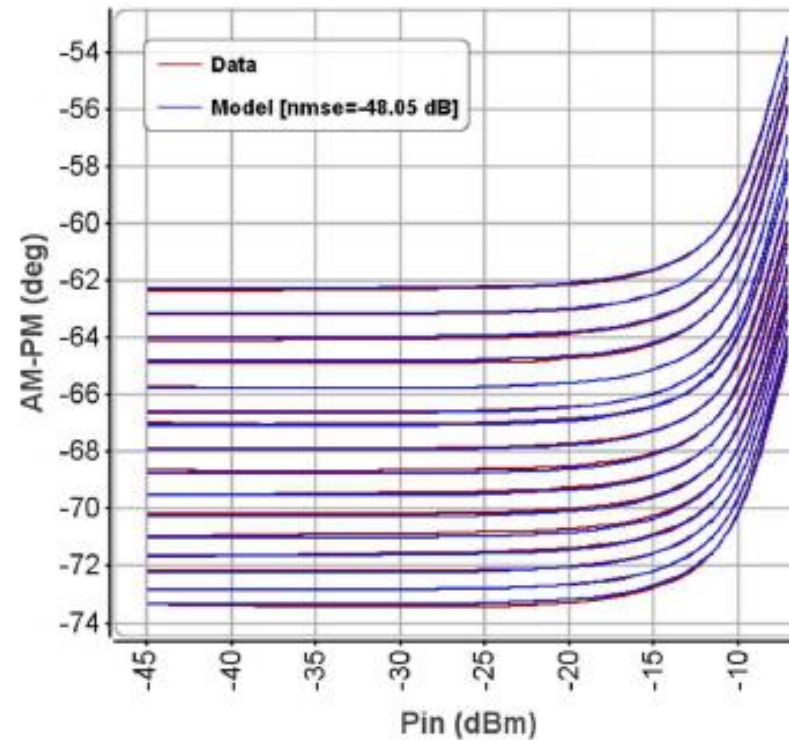
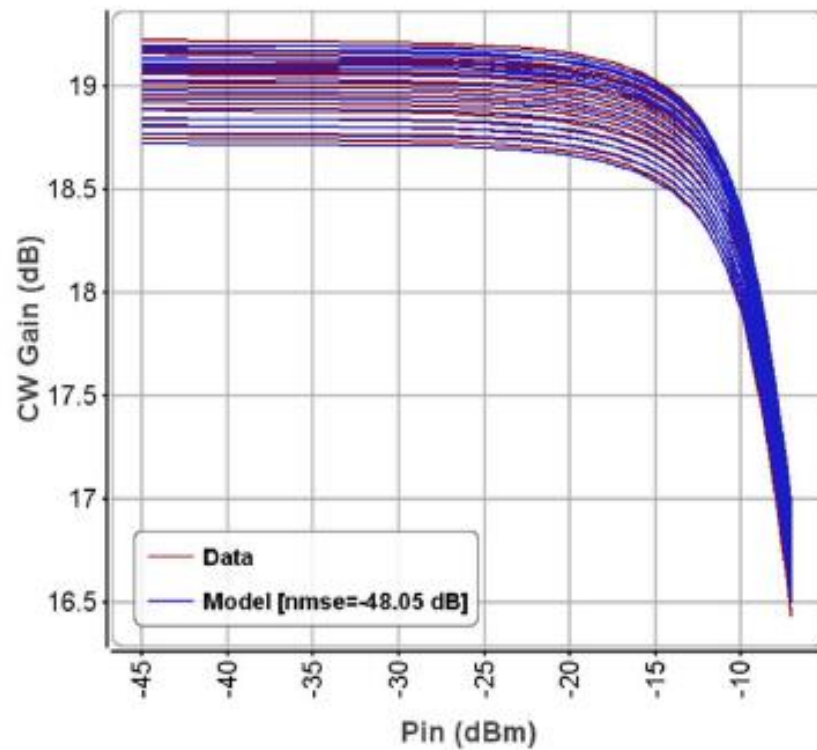
## 3-tone stimulus



- Require an accurate de-embedding procedure

# Application example

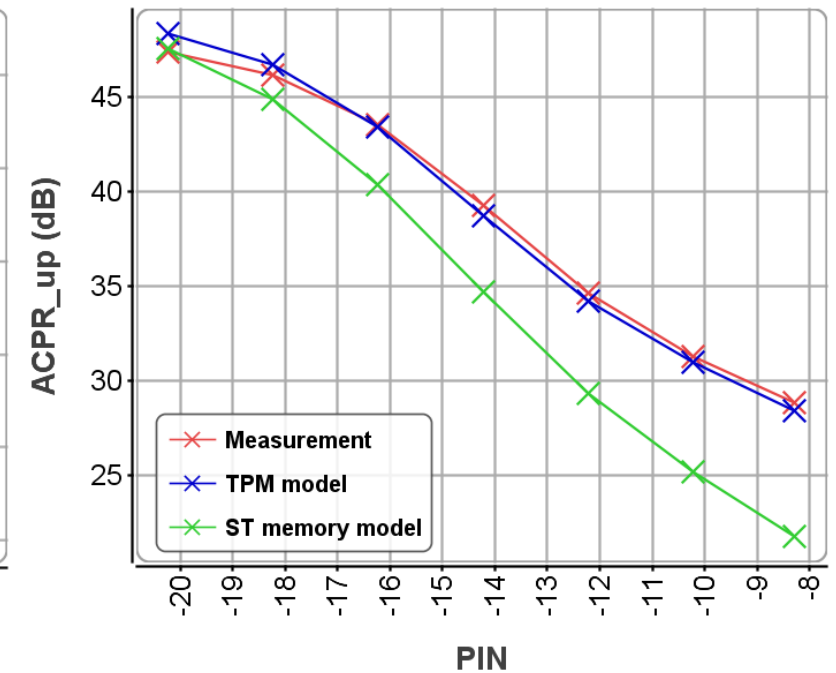
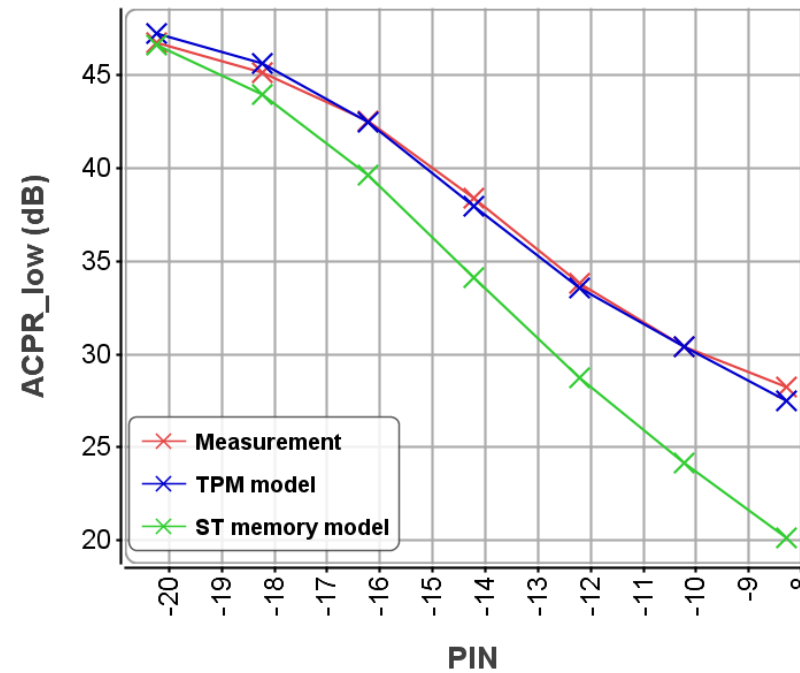
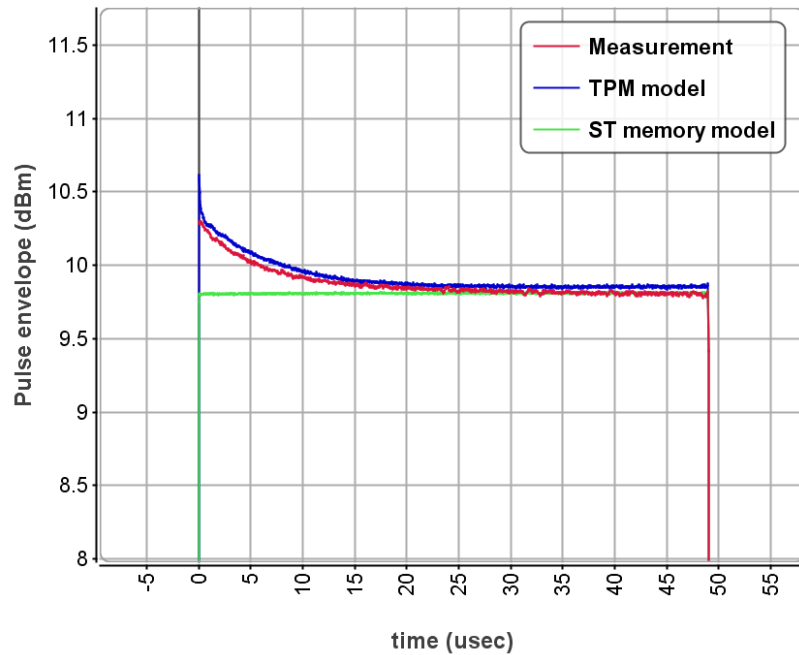
GaAs InGaP HBT Microwave Amplifier ; Output Power: 9 dBm at 3 GHz at P1dB



- ST memory model => AM-AM + AM-PM on 200 MHz bandwidth
- TPM model => AM-AM + AM-PM + 3-tone characterizations

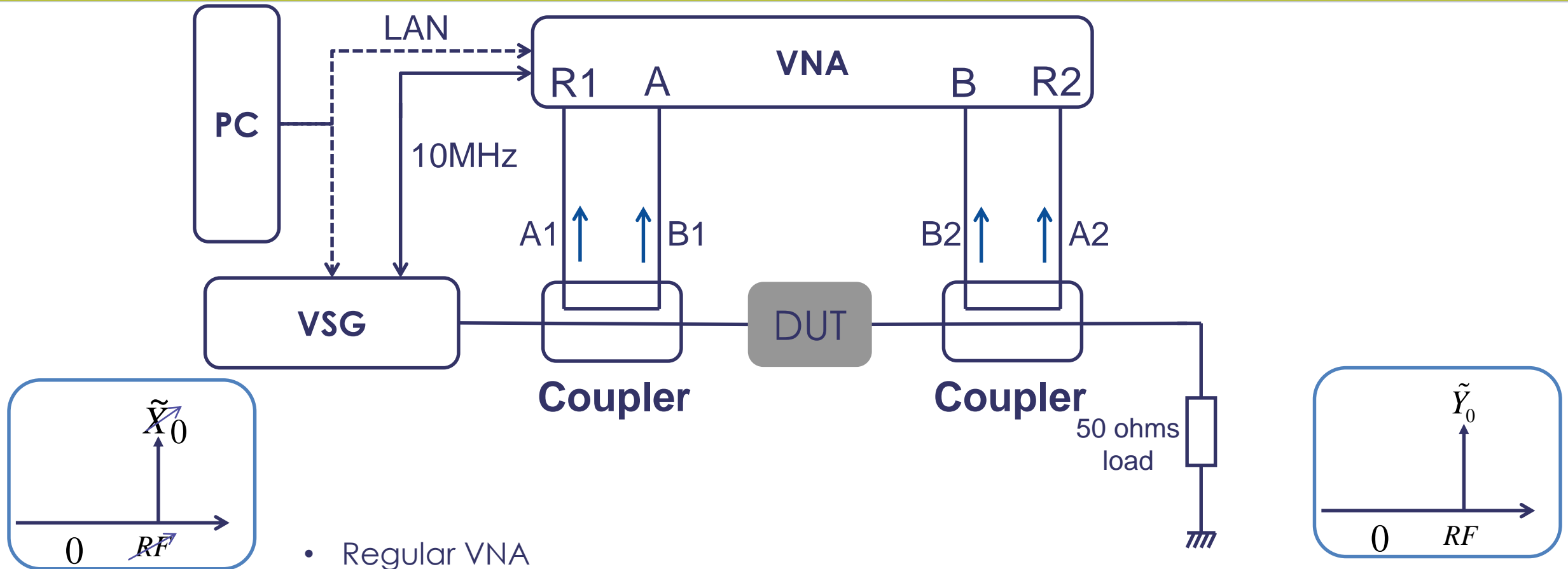
# Application example

## Comparison between measurements and simulations



- Pulse signal - period = 100 $\mu$ s, duty cycle = 50%
- Waveform - 256 QAM - Power = [-20dBm ; -8dBm], data rate = 42 MS/s, roll-off = 0.35

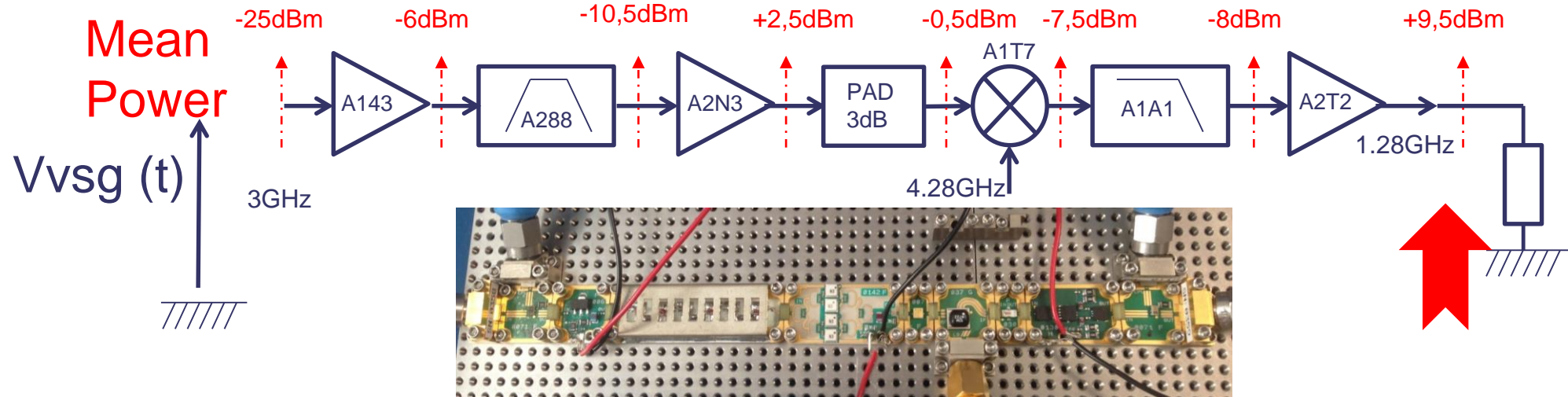
# Extraction



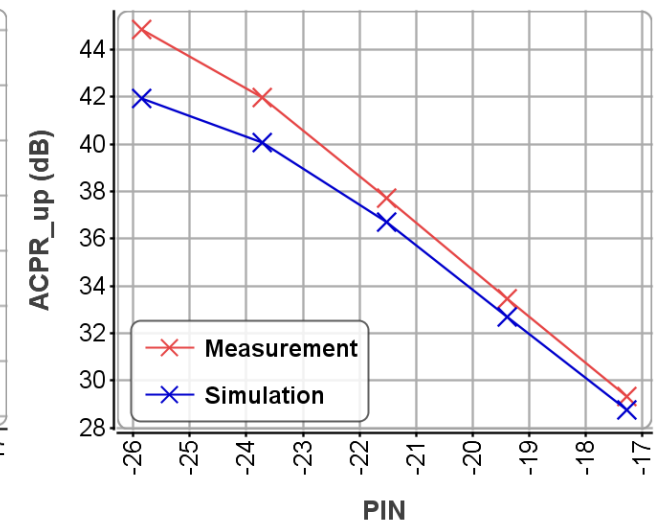
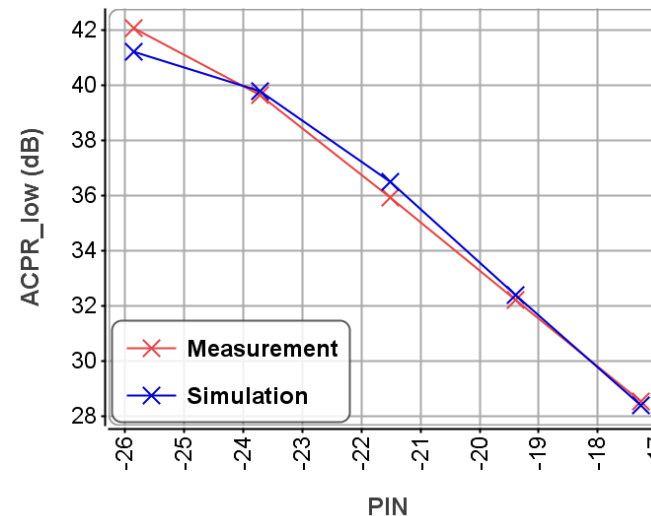
- Regular VNA
  - AM-AM and AM-PM measurements for several carrier frequencies
- => ST memory model dedicated to linear circuits, mixer...

# Application example

## Down-converter Front-end 3 GHz to 1.28 GHz



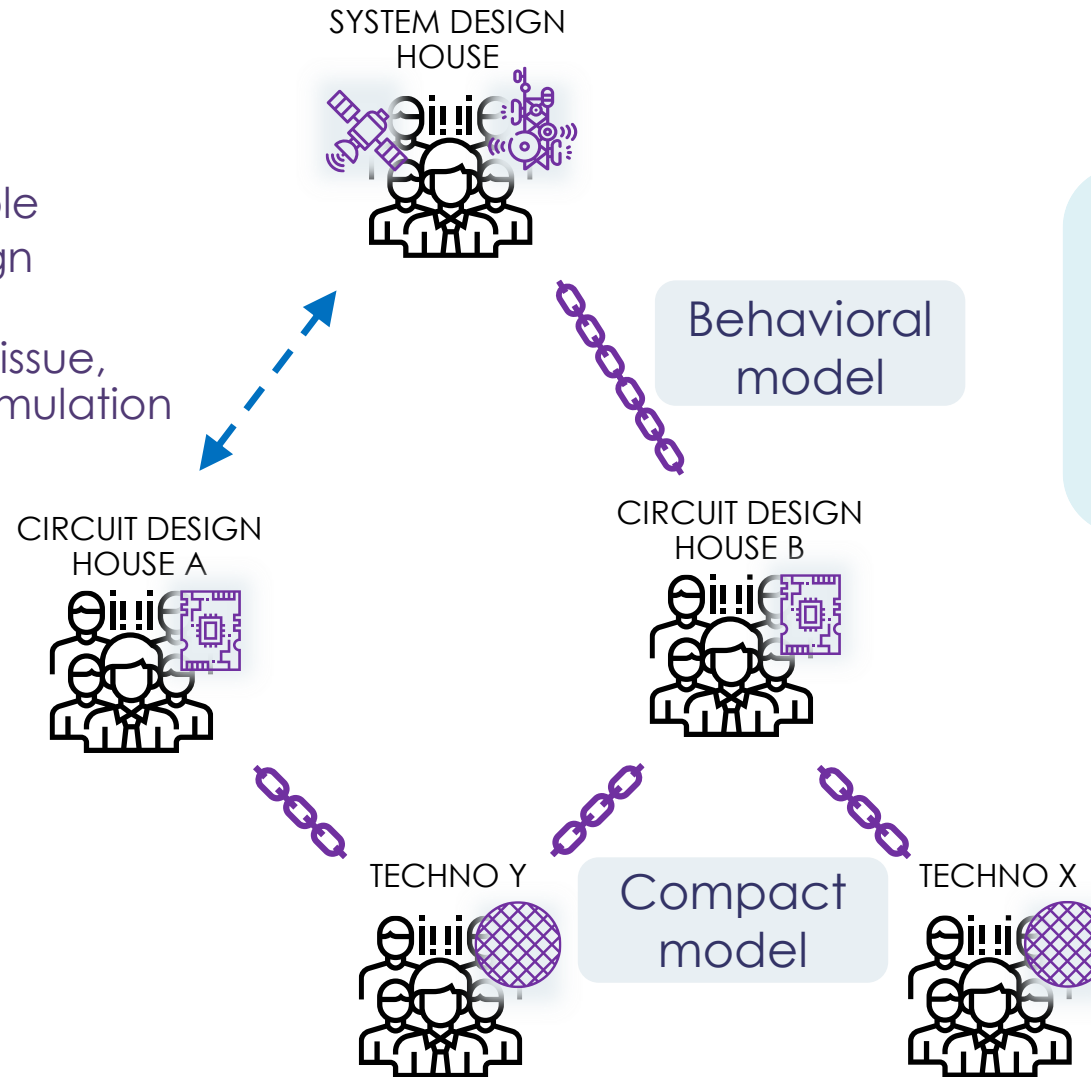
Waveform - 256 QAM  
 Power = [-26dBm ; -17,3dBm],  
 data rate = 42 MS/s, roll-off = 0.35





# Perspectives

- Datasheet
  - Look-up table
  - Circuit design
- => Sensitive IP,  
convergence issue,  
complex co-simulation



## Key competitive advantage for both

- Protected IP
- Wide domain of validity
- Model extraction from circuit simulation or measurement
- Fast simulation
- Integration in system simulator

# Conclusion

Complex analysis and optimization of system design in a mixed-domain:

- Large signal bandwidth and increasing number of circuits
- Memoryless model are not accurate enough
- Co-simulation between circuit and system level are not effective

Proposed technique:

- Behavioral models that take into account memory effects (short and long term)
- Wideband Test Bench and a comprehensive methodology to extract accurate model
- Standard RF hardware are used for extraction
- Key competitive advantage for both system and circuit designer

# Thank you for listening!

## Visit us in booth #328 for a Demo